

IN THE SPECIFICATION

[0025] Figures 4a, 4b, 4c, and 4d are cross section views of belleville washers having radially varying thicknesses of the type which are utilized in conjunction with an embodiment of the present invention, the belleville washer of Figure 4a-4 having a continuous washer shape shows a cross-sectional view of a belleville washer with a thinner inner portion than and a thicker outer,portion. the belleville washer of Figure 4b having a slotted washer shape with a thinner inner portion than outer, the belleville washer of Figure 4c having a continuous washer shape with a thicker inner portion than outer, and the belleville washer of Figure 4a having a slotted washer shape with a thicker inner portion than outer.

[0025.1] Figure 5 shows another cross-sectional view of a belleville washer, in accordance with another preferred embodiment of the present invention.

[0025.2] Figure 6 shows a cross-sectional view of a belleville washer with a thicker inner portion and a thinner outer portion, in accordance with another preferred embodiment of the present invention.

[0025.3] Figure 7 shows a cross-sectional view of a belleville washer, in accordance with another preferred embodiment of the present invention.

[0026] Figures 5a8a, 5b8b, and 5e8c are top views of the opposing plates, and more particularly, Figure 5a8a is a top view of the plate having a post element which seats within the central opening of the belleville washer, Figure 58b is a top view of the plate having the circumferential skirt an-and a retaining ring, in which a belleville washer of the type of either Figures 4a or 4c-4-7 is disposed within the skirt, and Figure 58c is a top view of the plate having the circumferential skirt an-and a retaining ring, in which a belleville washer of

the type of either Figures 4b or 4d-4-7 is disposed within the skirt.

[0027] Figures 6a₉, 6b₁₀, 6e₁₁, and 6d-12 are side cross-section views of various embodiments of the present invention which utilizes the corresponding belleville washers illustrated in Figures 4a-4d-4-7 mounted between the plates illustrated in Figures 3a and 3b.

[0030] Referring now also to Figures 5a-8a and 5b_{8b}, plate 100 further includes a circumferential skirt 106 which serves as a retaining wall, into which the large end of a belleville washer (see Figures 4a-4d-4-7) may be seated. The diameter of the retaining wall 106 is preferably slightly wider than the diameter of the undeflected belleville washer such that the loading thereof can result in an unrestrained radial deflection of the washer. The inner surface of the retaining wall 106 includes an annular recess into which a retaining ring may be provided for holding the belleville washer in place (see the assembled Figures 6a-6d₉₋₁₂).

[0031] Referring now also to Figure 5e_{8c}, plate 200 further includes a central post 206 which rises out of the interior face 208 at a nearly perpendicular angle. The top of this short post member 206 includes a ball-shaped head 210. The head 210 includes a series of slots 212 which render it compressible and expandable in correspondence with a radial pressure (or a radial component of a pressure applied thereto). There is a central threaded axial bore 214 which extends down the post 206. This threaded bore 214 is designed to receive a small set screw 216. Prior to the insertion of the set screw 216, the ball-shaped head 210 can deflect radially inward (so that the ball-shaped head contracts) permitting the belleville washer to be flexibly mounted thereon. The insertion of the set screw 216 eliminates (or greatly reduces) the capacity for this deflection.

[0032] Referring now to Figures 4a-4d-4-7, side cross-section

views of four separate embodiments of the belleville washers are provided. In general, these belleville washers 130 comprise a domed circular shape (a section of a sphere or three dimensional paraboloid would be an appropriately corresponding shape), having a central opening 132 and an outer edge 134. As a compressive load is applied to a belleville washer, the forces are directed into a hoop stress which tends to radially expand the washer. This hoop stress is counterbalanced by the material strength of the washer, and the strain of the material causes a deflection in the height of the washer. Stated equivalently, a belleville washer responds to a compressive load by deflecting compressively, but provides a restoring force which is proportional to the elastic modulus of the material in a hoop stressed condition. In the present invention, the thickness (the distance from the concave surface to the convex surface) of the material which comprises the washer varies from the edge of the central opening 132 to the outer edge 134 of the element.

[0033] More particularly with respect to the washer in Figure 4a₄ (and shown within the circumferential ring of plate 100 in Figure-5b8b), the belleville washer 130a has a greater thickness at the outer edge 134a than at the edge of the central opening 132a. As the restoring force of a belleville washer is proportional to the elastic properties of the material as well as the quantity of material being loaded, the reduction of the material at the edge of the central opening 132a permits a load/deflection profile in which the load which deflects the inner portion of the washer is less than the outer portion. This permits the washer to compress to initially compress easily under a light loading, but to rapidly (faster than a straight linear loading profile) become stiff and resist deflection. This loading profile is more anatomically relevant with respect to mimicking the performance of the cartilage present in a healthy intervertebral space.

[0034] More particularly with respect to the washer in Figure 4b-5 (and shown within the circumferential ring of plate 100 in Figure-5e10), the belleville washer 130b also has a greater thickness at the outer edge 134b than at the edge of the central opening-132b. However, the washer further includes a series of spiral slots 138b extending from the outer edge 134b toward the central opening 132b. The slots 138b extend from the outer diameter of the belleville washer, inward along arcs generally directed toward the central opening 132b of the element. The slots 138b do not extend fully to the center of the device. In preferred embodiments, the slots may extend anywhere from a quarter to three quarters of the overall radius of the washer, depending upon the requirements of the patient, and the anatomical requirements of the device. As the restoring force of a belleville washer is proportional to both the geometry of the material being loaded and its elastic properties, the varying thickness combined with the radial slots 138b permits a load/deflection profile in which the load which deflects the inner portion of the washer is less than the outer portion. This permits the washer to compress to initially compress easily under a light loading, but to rapidly (faster than a straight linear loading profile) become stiff and resist deflection. This loading profile is more anatomically relevant with respect to mimicking the performance of the cartilage present in a healthy intervertebral space.

[0035] More particularly with respect to the washer in Figure 4e-6 (and shown within the circumferential ring of plate 100 in Figure-5b11), the belleville washer 130c has a smaller thickness at the outer edge 134c than it is at the inner edge 132c. As the restoring force of a belleville washer is proportional to the elastic properties of the material as well as the quantity of material being loaded, the reduction of the material at the outer edge 134c permits a load profile in which the load which

deflects the outer portion of the washer is less than the inner portion. This permits the washer to compress to initially compress easily under a light loading (as a result of outer edge deflection), but to rapidly (faster than a straight linear loading profile) become stiff and resist deflection. This loading profile is more anatomically relevant with respect to mimicking the performance of the cartilage present in a healthy intervertebral space.

[0036] More particularly with respect to the washer in Figure 4d-7 (and shown within the circumferential ring of plate 100 in Figure 5e12), the belleville washer 130d has a smaller thickness at the outer edge 134d than at the edge of the central opening 132d. However, the washer further includes a series of spiral slots 138d extending from the outer edge 134d toward the central opening 132d. The slots 138d extend from the outer diameter of the belleville washer, inward along arcs generally directed toward the central opening 132d of the element. The slots 138d do not extend fully to the center of the device. In preferred embodiments, the slots may extend anywhere from a quarter to three quarters of the overall radius of the washer, depending upon the requirements of the patient, and the anatomical requirements of the device. As the restoring force of a belleville washer is proportional to both the geometry of the material being loaded and its elastic properties, the varying thickness combined with the radial slots 138d permits a load/deflection profile in which the load which deflects the inner portion of the washer is less than the outer portion. This permits the washer to compress to initially compress easily under a light loading, but to rapidly (faster than a straight linear loading profile) become stiff and resist deflection. This loading profile is more anatomically relevant with respect to mimicking the performance of the cartilage present in a healthy intervertebral space.

[0037] In addition, the central openings of each of the belleville washer embodiments described hereinabove further includes a curvate volume ~~136a, 136b, 136c, 136d~~ for receiving therein the ball-shaped head 210 of the post 206 of the lower plate 200 described above.

[0038] Referring now to Figures ~~6a-6d~~9-12, side cross-sectional views of the fully assembled embodiments of the intervertebral spacers which comprises the present invention are provided. Each structure includes the belleville washer (selected from the corresponding ones illustrated in Figures ~~4a-4d~~4-7). Each further includes the following common features: two opposing plates 100,200 having their flat surfaces 102,202, respectively, directed away from one another (to be seated against the adjacent bone); a retaining ring 110 is seated in the annular groove of the retaining wall 106; and a ball-shaped-headed central post 206 extending into the central opening 132 of the corresponding belleville washer 130, rotatably secured in place by set screw 216. The deflectability of the ball-shaped head of the post 206, prior to the insertion of the set screw 216, permits the head to be inserted into the interior volume at the center of the belleville washer 130. Subsequent introduction of the set screw 216 into the axial bore of the post 206 prevents the ball-shaped head from deflecting. Thereby, the washer 130 can be secured to the ball-shaped head so that it can rotate thereon through a range of proper lordotic angles. While not in this preferred embodiment, it should be noted that in other embodiments, a tightening of the set screw can lock the washer 130 on the ball-shaped head at one of the lordotic angles.